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A BATTERY FOR ARCTIC RADIO REPEATER SYSTEMS.(U)
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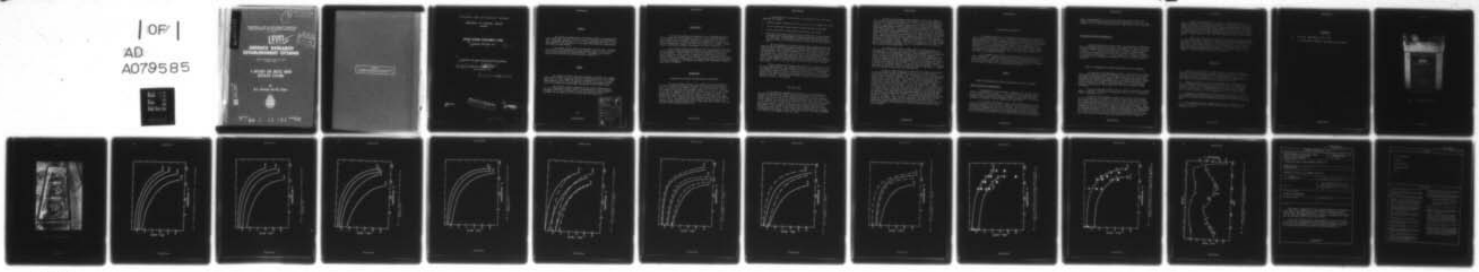

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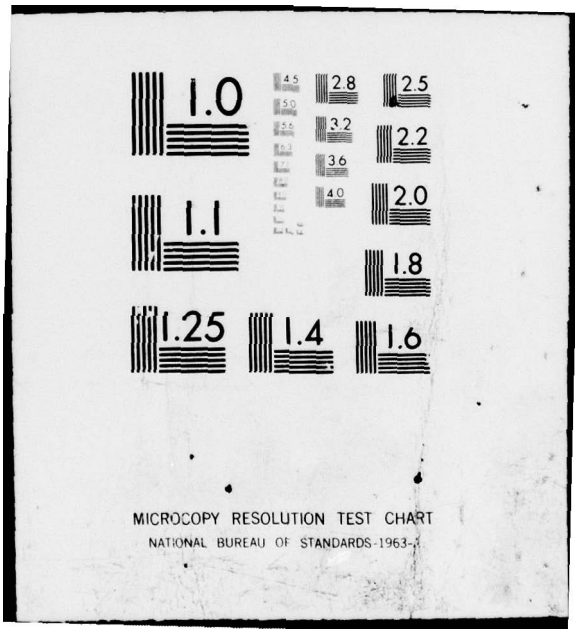
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DREO TECHNICAL NOTE NO. 79-27
DREO TN 79-27

A BATTERY FOR ARCTIC RADIO REPEATER SYSTEMS

by
W.A. Armstrong and W.D. Barnes

PROJECT NO.
25A

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NOVEMBER 1979
OTTAWA

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CANADA

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

(9) TECHNICAL NOTE NO. 79-27 (12) 26

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A BATTERY FOR ARCTIC RADIO REPEATER SYSTEMS.

by (10) Williams R.A./Armstrong W.D./Barnes
Energy Conversion Division

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ABSTRACT

The effect of temperature on the working voltage of air depolarized cells (Model 608z, 2000 Ah) at various stages of discharge has been investigated. Discharge currents of 0.2 to 1.0 A at temperatures from 20°C to -55°C were examined as were the effects of increasing the elecrolyte concentration from 22% to 27% and 29% KOH.

The results confirm that air depolarized cells can form a suitable power source for an unattended 30 W radio repeater station in the arctic if the cells are connected in a series/parallel arrangement such that the current drain from each cell does not greatly exceed 0.2 A.

RÉSUMÉ

On a étudié, à divers niveaux de décharge, l'influence de la température sur la tension de service des piles à dépolarisation par l'air (modèle 608z, 2000 Ah). On a étudié les courants de décharge de 0.2 à 1.0 A à des températures de 20°C à -55°C, de même que les effets qu'entraînent l'élévation de la concentration de KOH dans l'électrolyte de 22% à 27% et 29%.

Les résultats obtenus confirment que les piles à dépolarisation par l'air constituent la source idéale d'alimentation des relais hertziens autonomes de 30 W dans l'Arctique si elles sont groupées en série ou en parallèle afin de limiter à 0.2 A la perte subie par chaque pile.

INTRODUCTION

A review has recently been published (1) of candidate sources of electric power for a radio repeater system. At the time of publication it was envisaged that each repeater station would require about 30 watts of power and would have to operate reliably and unattended for a period of one year at temperatures between -55°C and 30°C in winds up to 120 mph. Further details concerning the general requirements are given in reference 1.

Of the power sources considered only the air depolarized (zinc/air) primary battery was both immediately available and judged likely to meet all the requirements. However there was little data available to define the power limitations of the battery at temperatures lower than -40°C and at various stages of discharge. There was also a lack of information about the effects of varying the concentration of potassium hydroxide in the electrolyte on battery performance. The present investigation was undertaken in order to obtain this information.

EXPERIMENTAL

DESCRIPTION OF THE CELL AND THE METHOD OF ACTIVATION

The only available zinc/air cell suitable for the application is the 608z Air Depolarized Primary Cell made by SAFT Batteries Ltd (formerly Cipel et Le Carbone), Valleyfield, Quebec. This cell, pictured in Fig.1, has a capacity of 2000 Ah and a working voltage of 1.4 to 1.0 V. The height is 28.0 cm, the dimensions of the base 21.0 X 21.0cm; the dry weight is 9.5 kg and when activated by the addition of water the weight is 14 kg. The manufacturer states that the cell will operate over the temperature range -40°C to 45°C with a maximum continuous discharge current of 2 A at 20°C and 0.2 A at -40°C. The shelf life is said to be 5 years unactivated in the original packing (which prevents entry of oxygen and carbon dioxide from the air) and 3 years following initial use.

The manufacturer's instructions for activation of the cell can be summarized as follows:

1. Carefully remove aluminum foil cover; take care not to damage the carbon.

2. Cut out centre part of grey plastic filling hole with a pen knife.

3. Cut out centre part of grey plastic circle with a pen knife.

4. Slowly pour sufficient fresh water into filling hole to bring solution to maximum level (approximately one gallon) and check solution level with indicator. As solid KOH is located at both the top and bottom of the cell mixing is not required to get a uniform electrolyte concentration.

The time necessary to activate the 120 cells required to power one station would be excessive if these instructions were followed exactly. We found that Step 2 can be simplified if a piece of thin-walled pipe (1.9 cm outside diameter) which has been sharpened at one end is used to knock open the filling hole. The plastic circle cut out in this manner may fall into the battery but will not cause problems. Step 3 can be eliminated if a funnel with a fluted spout is used in the filling process or if the end of a piece of small diameter plastic tubing (2 mil) is inserted into the filling hole along the side of the funnel spout so that air can be vented through the tubing.

After activation the filling hole should not be completely blocked for any prolonged period. Gas pressure could then build up within the cell and damage the carbon electrode. However, if cells are to be transported in the activated state for a period of not more than 8 hours, a solid rubber stopper can be inserted into the filling hole to prevent electrolyte leakage during the journey. Provisions must be made to ensure that the stopper is removed at the end of the journey.

TEST CONDITIONS

In the review of candidate power sources (1) it was assumed that the voltage regulator will accept input voltages between 10.0 and 18.0V. Between 13.6 and 18.0V the output voltage is constant at 13.4V but decreases linearly from 13.4 to 9.8V as the input voltage drops from 13.6 to 10V. The current required from the battery is between 1.62 and 2.2A. Based on this data it was concluded that a battery made up of 10 strings connected in parallel, each string having 12 zinc/air cells connected in series, would meet the requirements. The voltage of the battery would decrease from 16.8 to 10.2V during its working life if a lower voltage limit of 0.85V per cell is assumed. By paralleling the strings of cells the current required from each individual cell would be in the range of 0.162 to 0.22A.

In view of the foregoing it was decided to record the change in cell voltage with increasing current drain from 0.2 A up to the current at which the cell voltage fell below 0.85 V. This was done by discharging the cell into a variable 25 W resistor, measuring the current with a Sensitive Research Ammeter Model UPP and recording the cell voltage with a Keithley Electrometer Model 610C. The procedure was carried out with cells at various stages of discharge and at temperatures of -55°C, -50°, -45°, -40°, -20° and room temperature. Discharges at other than room temperature were carried out after a cell had been left to equilibrate for at least 18 hours in an environmental chamber which maintained the temperature desired to within $\pm$ 0.5C°. Normally the steady-state cell voltage was noted after about five minutes of discharge at any given current. However at -55°C and 0.2 A, the most stringent of the specified conditions, the cell was discharged for at least 4 hours before the voltage was recorded. There is no evidence that this very low drain warmed the cell appreciably.

Two methods were used to bring a cell to the desired state of discharge prior to testing. The first consisted of discharging the cell at room temperature at the maximum continuous rate recommended by the manufacturer (2 A) until the required number of ampere-hours had been expended. A freshly activated cell would first be tested over the full temperature range; 1000 Ah of capacity then would be withdrawn (500 h at 2 A) and the cell re-tested, an additional 500 Ah withdrawn and the cell tested again and, finally, a further 300 Ah and the cell re-tested. Thus prior to the final testing about 90% of the nominal capacity of the cell had been expended. This method permitted the collection of data at different states of discharge in a reasonably short period of time (less than three months).

It was not known whether cells tested in this manner would perform in the same manner as cells discharged at the much lower current drains specified for the repeater station. For this reason a set of cells was placed at an out-door location at Shirley's Bay. Three cells in a row were housed as shown in Fig. 2 in a box, made of 3/4" plywood, of inner dimensions just sufficient to contain the cells. Holes, 2.5 cm diam., drilled along the top of each side to permit the free access of air were covered with screen to minimize the entry of foreign matter. The box was covered with a tightly fitting lid which protected the cells from rain and snow. No attempt was made to insulate the box. Each cell was connected separately by electrical cables to its own variable load located inside a hut along with the necessary recording equipment. The individual cell voltages measured at the cell terminals and the discharge currents were recorded. The cells were continuously discharged at a constant current of 0.2A. The out-door temperature was monitored during the discharge. After six months and again after nine months of discharge the cells were brought into the laboratory, subjected to the low temperature testing described above and then returned to the out-door site for further discharge at 0.2A. This part of the test program continued for more than 18 months.

ELECTROLYTE CONCENTRATION

Information supplied by the manufacturer stated that the concentration of potassium hydroxide in a cell activated by the addition of water in the normal manner is about 22%, a value significantly lower than that used in other alkaline batteries. No data concerning the effect of an increase in the KOH concentration on cell performance, particularly at low temperatures, was available. It was therefore decided to raise the KOH concentration of some cells to about 27% and others to about 29%. This was done by adding pellets of reagent grade potassium hydroxide (250g for 27% and 400g for 29%) to the cell prior to the addition of water.

The freezing points for 22%, 27% and 29% KOH are about -40°,-50° and -60°C, respectively. Potassium hydroxide solutions do not freeze solid at a given temperature. Rather ice crystals form and the remaining solution is left more concentrated in KOH. The internal resistance of the cell increases but not enough to affect low rate discharges significantly (2).

RESULTS

EFFECT OF TEMPERATURE ON VOLTAGE AFTER PERIODS OF RAPID DISCHARGE

NORMAL ELECTROLYTE CONCENTRATION

The dependence of cell voltage on temperature for various current drains is illustrated in Figures 3 - 6 for cells which had been activated by the addition of the amount of water suggested by the manufacturer and brought to various states of discharge by rapid discharge (2A). The curves represent the average of values obtained with three cells.

It is evident from Figures 3 and 4 that the performance of a cell from which 1000 Ah (50% of the nominal capacity) had been withdrawn was not appreciably different from that of a fresh cell. In both cases a drain of 0.3A could be supported at -55°C with a cell voltage of about 0.9V. After further discharge the performance at low temperature decreased significantly. Cells from which three-quarters of the nominal capacity had been discharged

(Fig. 5) would support a 0.2 A drain at -55°C while after 90.0% of the capacity had been removed (Fig. 6) the lowest temperature at which the cell voltage of 0.9 V could be maintained with a current drain of 0.2 A was -50°C.

INCREASED ELECTROLYTE CONCENTRATION

Results obtained with cells in which the electrolyte concentration had been increased to either 27% or 29% by the addition of 250 g or 400 g of potassium hydroxide prior to activation by the addition of water are plotted in Figures 7 - 10. Cells with 29% KOH gave, in general, somewhat higher voltages at low temperatures than those with 27% KOH. However if Figures 7-10 are compared with Figures 3 - 5 it is evident that the addition of KOH did not improve the low temperature performance of cells at various states of discharge.

EFFECT OF TEMPERATURE ON VOLTAGE AFTER PERIODS OF SLOW DISCHARGE

As described in the Experimental Section, cells were also evaluated after six and nine month periods of discharge at a current of 0.2 A, a value approximately that expected in the 30 W radio repeater system. These cell discharges were started on 21 December 1976. The results recorded in Figures 11 and 12 do not differ significantly from those obtained with cells which had been subjected to periods of rapid discharge (2 A). The deleterious effects of increasing the KOH concentration were also confirmed in these experiments.

The most significant finding is that a cell activated in the normal manner is capable of functioning at temperatures down to -55°C following nine months of discharge at 0.2 A.

During the slow discharge of cells at the out-door location both the cell voltages and the average daily ambient temperatures were recorded. These values are plotted in Fig. 13. Only the results from the cell having the standard KOH concentration (22%) are shown as the voltages of cells with increased electrolyte concentration were not significantly different. Winter temperatures were not low enough to demonstrate differences in voltage related to electrolyte concentration. The duration of discharge was also independent of the KOH concentration. Both the cell with 22% electrolyte and the one with 29% ran out on day 579 (18 July 1978) having delivered 2779 Ah of capacity. The cell with 27% KOH electrolyte lasted until day 587 (2818 Ah).

Figure 13 illustrates very clearly how temperature affects the working voltage of the cell and how this effect is more important at advanced stages of discharge. During January 1977 while the average daily temperature ranged from -5 to -15°C the cell voltage remained close to 1.30 V. From June to August 1977 with average daily temperatures of 20 to 25°C the cell voltage was approximately 1.35 V. During the second winter (January, February 1978), the cell voltage dropped to 1.25 V and only recovered to about 1.30 V in June 1978.

During this long period of operation the growth of potassium carbonate deposits was noted. These can be seen in Fig. 2 around the carbon cathodes and along the top edges of the cells. They were formed as a result of the reaction of carbon dioxide from the air with potassium hydroxide electrolyte which had crept up through hair-line cracks in the asphalt sealant. The deposits did not interfere with the operation of the cells and there was no leakage of electrolyte down the sides of the cells.

CONCLUSIONS

1. The results of this study confirm the previous tentative conclusion that the air depolarized cells can form a suitable power source for a remote unattended 30 W radio repeater station at temperatures as low as -55°C provided the cells are connected in a series/parallel arrangement such that the current drain from each cell does not greatly exceed 0.2A.

2. Although the ability of the air depolarized cell to provide power at very low temperatures decreases with the decreasing state of charge of the battery the effect is not serious during the first 1000 Ah of discharge. Thus if a battery were to be installed during the summer months it would still be able to operate at -55°C temperatures six to nine months later.

3. Increasing the concentration of the electrolyte from 22% to 27% or 29% by the addition of potassium hydroxide pellets prior to activation with water does not improve the low temperature capabilities of the air deplorized cell.

4. In our experience the air depolarized cell is very reliable . All cells tested gave more than the nominal 2000 Ah capacity. There were no premature failures.

REFERENCES

1. G.D. Nagy. DREO Report No. 787 (1978)

2. G. Verville and K. Feldman. DREO Report No. 816 (1979).

Fig. 1: Air Depolarized Primary Cell.

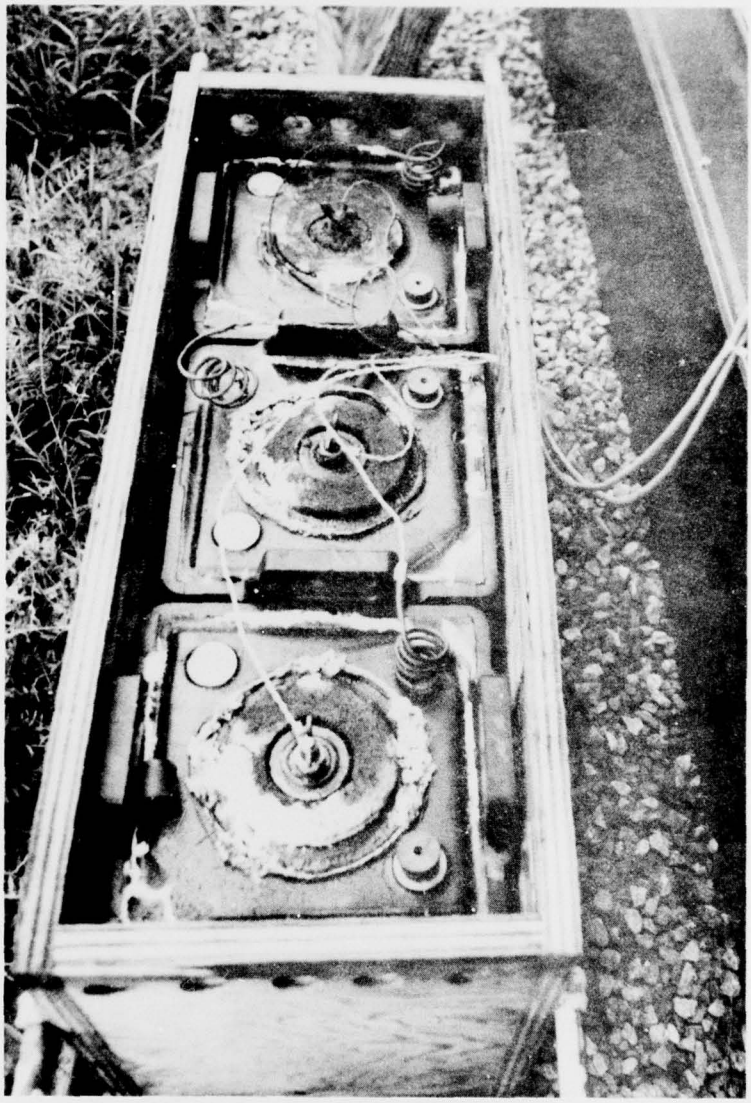

Fig. 2: Cells at Out-Door Site.

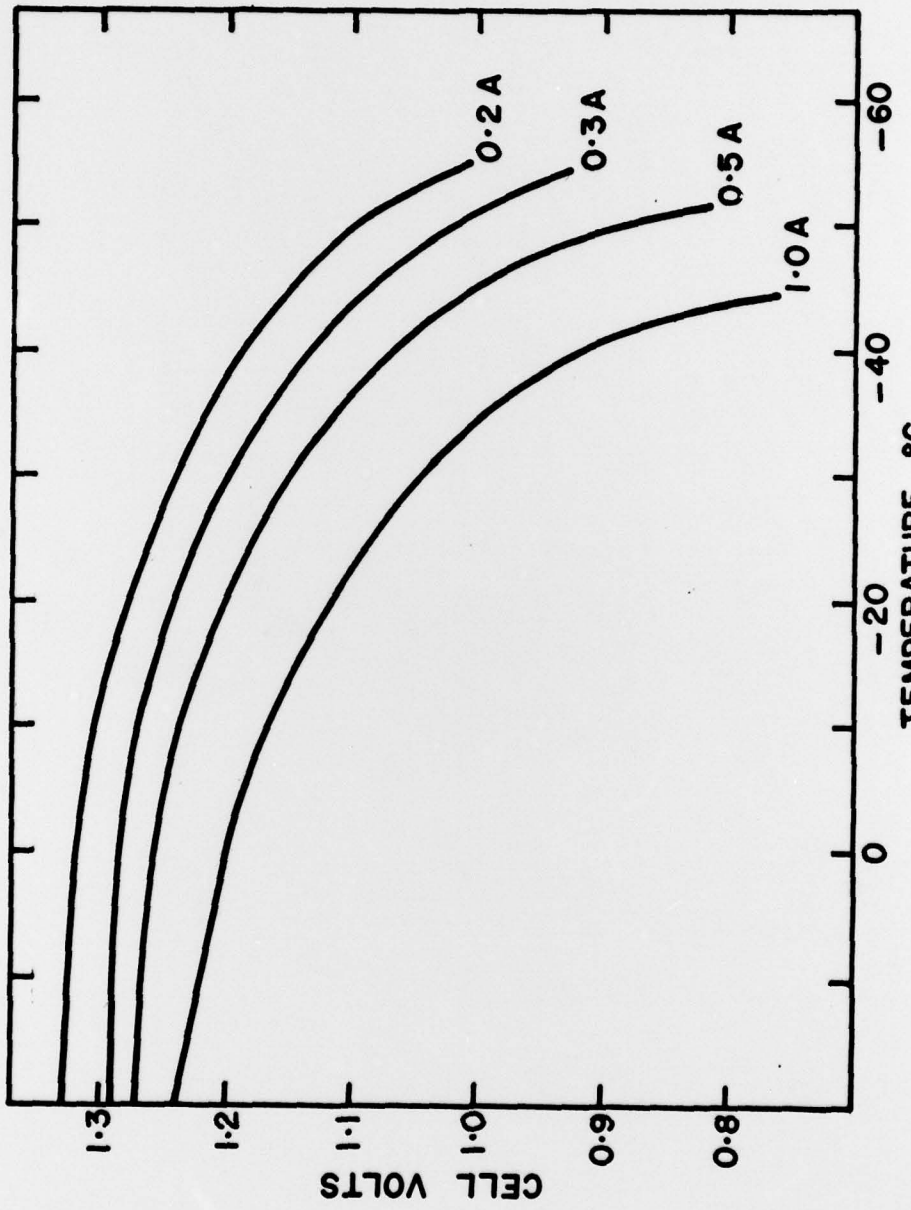

Fig. 3: Effect of Temperature on Cell Voltage - Initial Performance.

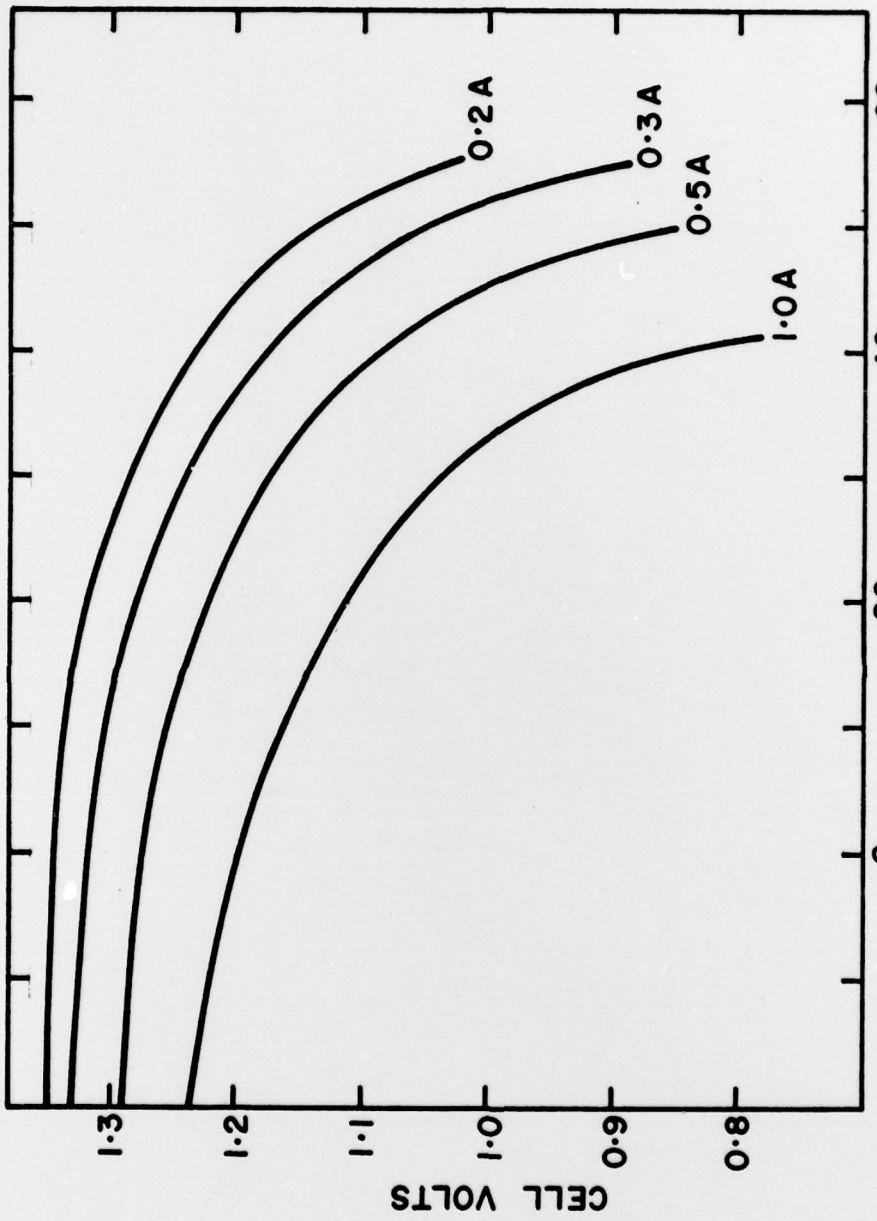

Fig. 4: Effect of Temperature on Cell Voltage After 1000 Ah Discharge at 2A.

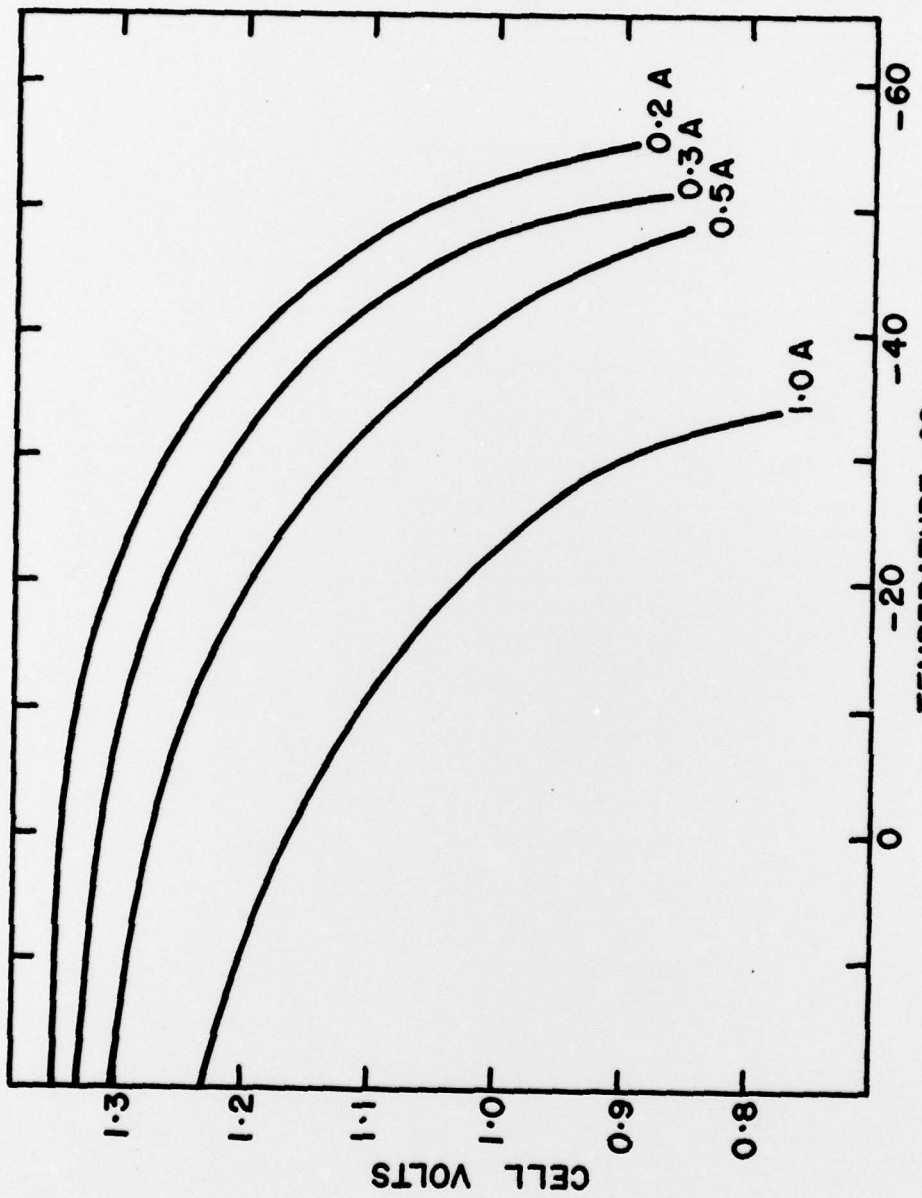

Fig. 5: Effect of Temperature on Cell Voltage After 1500 Ah Discharge at 2A.

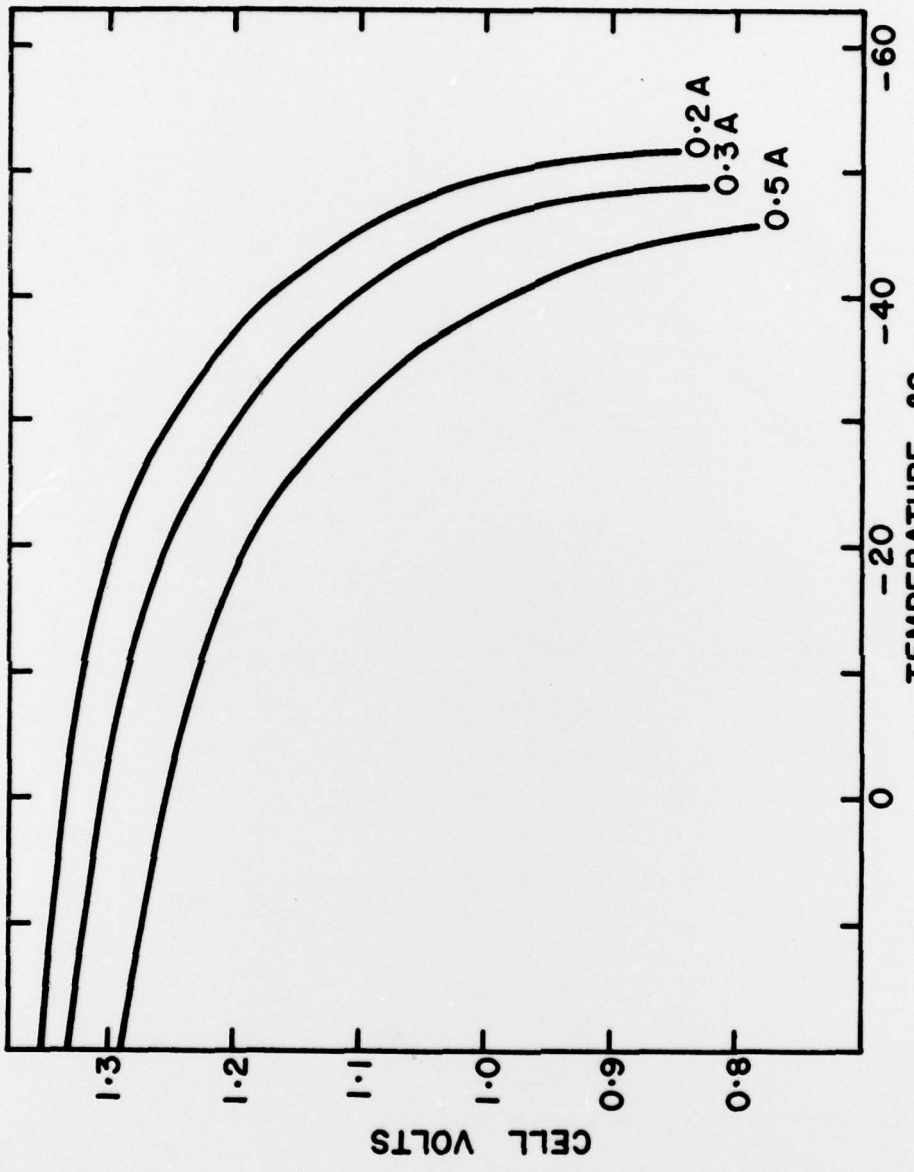

Fig. 6: Effect of Temperature on Cell Voltage After 1800 Ah Discharge at 2A.

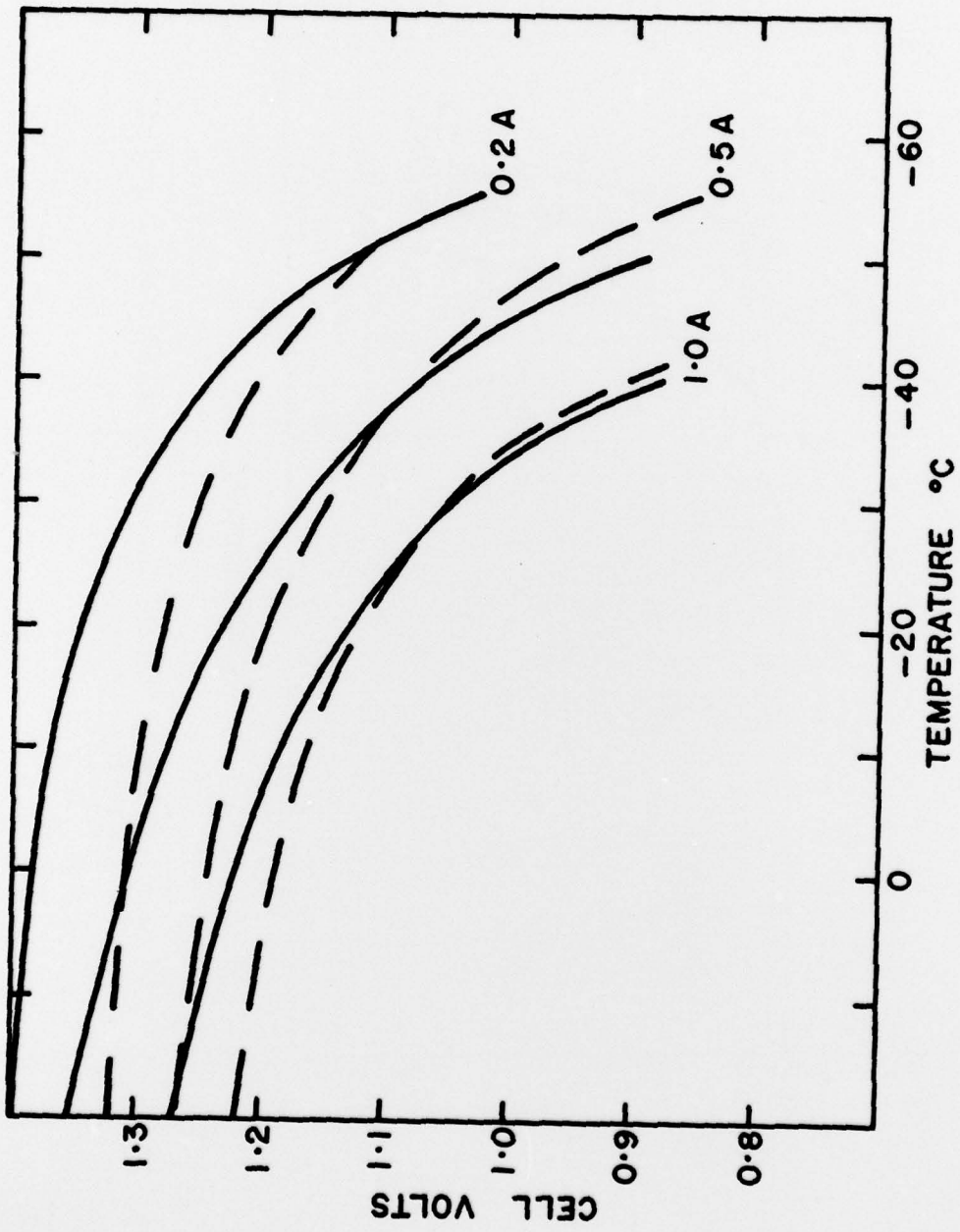

Fig. 7: Effect of Increased KOH Concentration on Initial Performance.
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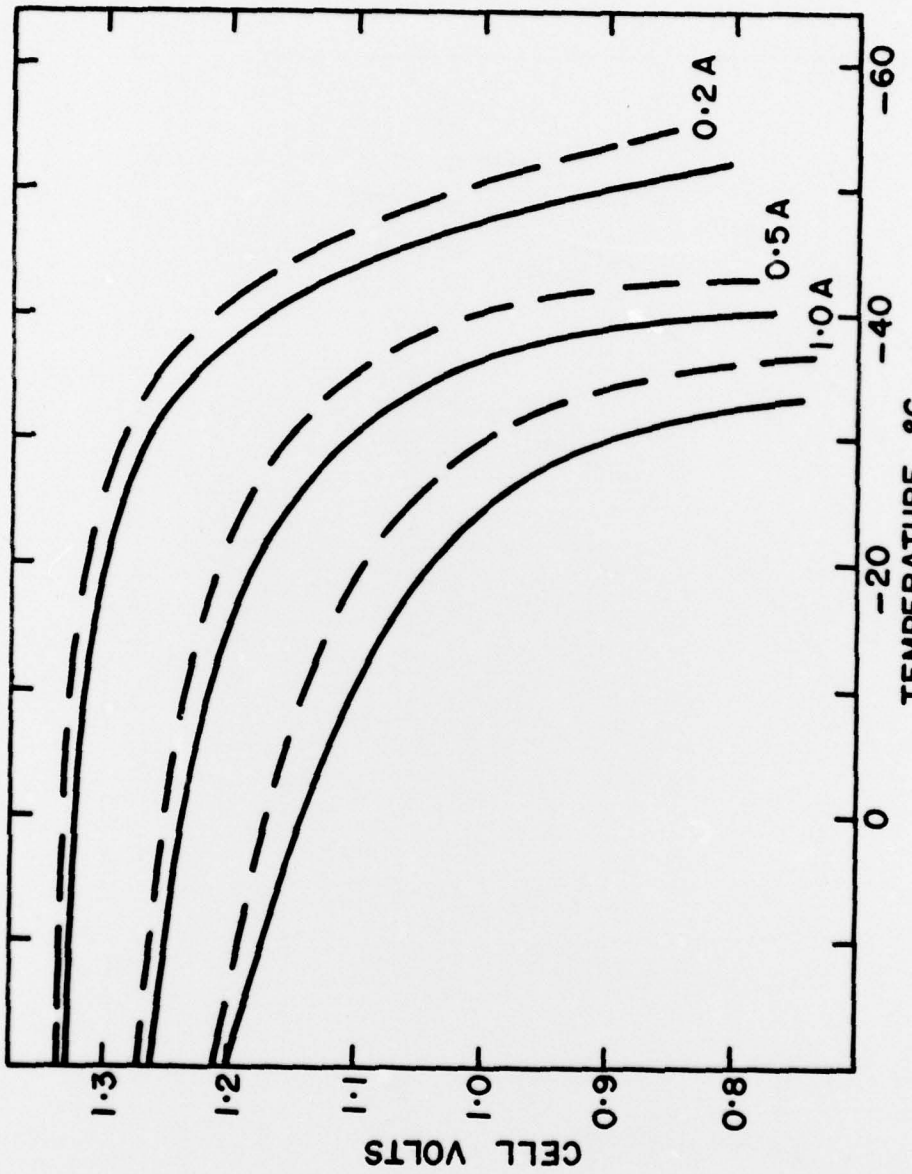

Fig. 8: Effect of Increased KOH Concentration After 1000 Ah Discharge at 2A.
——— 27% KOH, ------- 29% KOH.

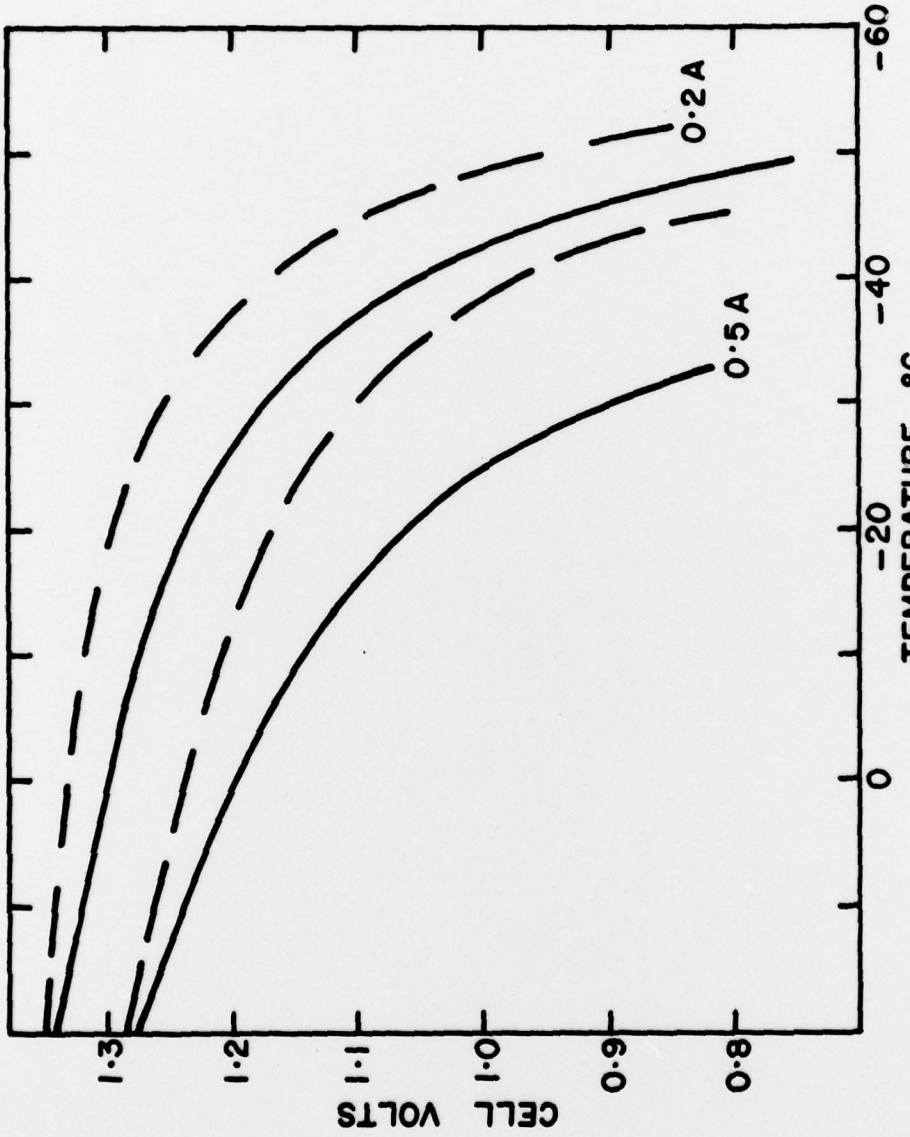

Fig. 9: Effect of Increased KOH Concentration After 1500 Ah Discharge at 2A. _____ 27% KOH, ------ 29% KOH.

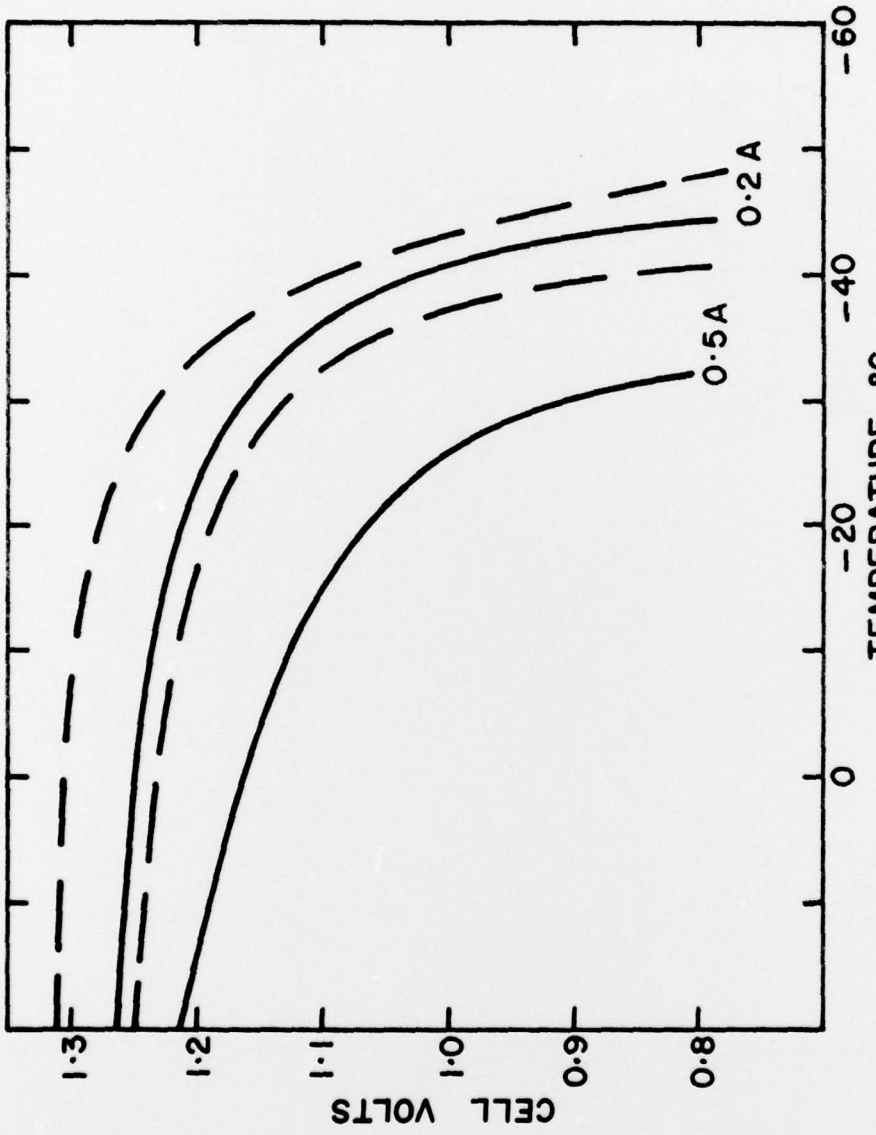

Fig. 10: Effect of Increased KOH Concentration After 1800 Ah Discharge at 2A. _____ 27% KOH, ------ 29% KOH.

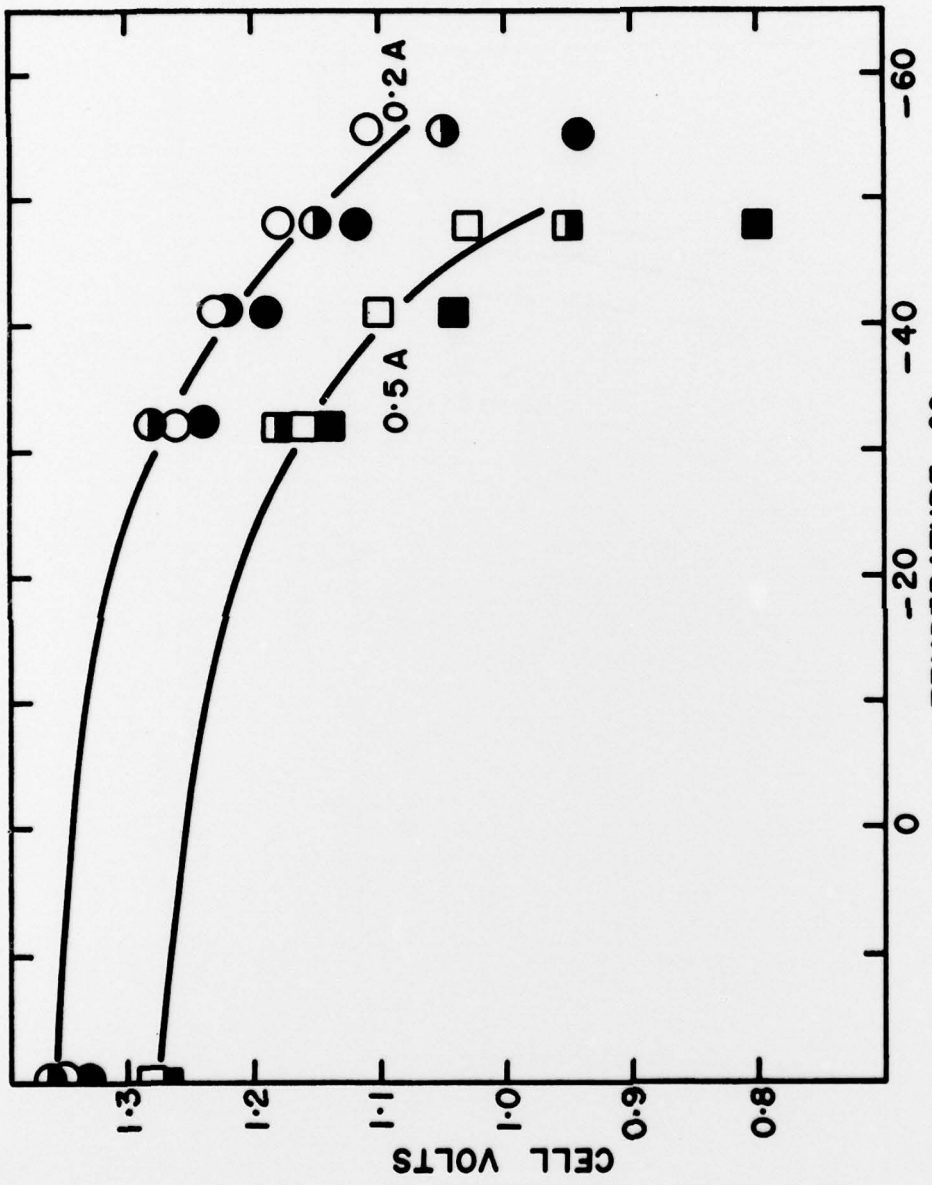

Fig. 11: Effect of Temperature on Cell Voltage After Six Month Discharge at 0.2A. □,○ 22% KOH, ◪,◐ 27% KOH, ■,● 29% KOH.

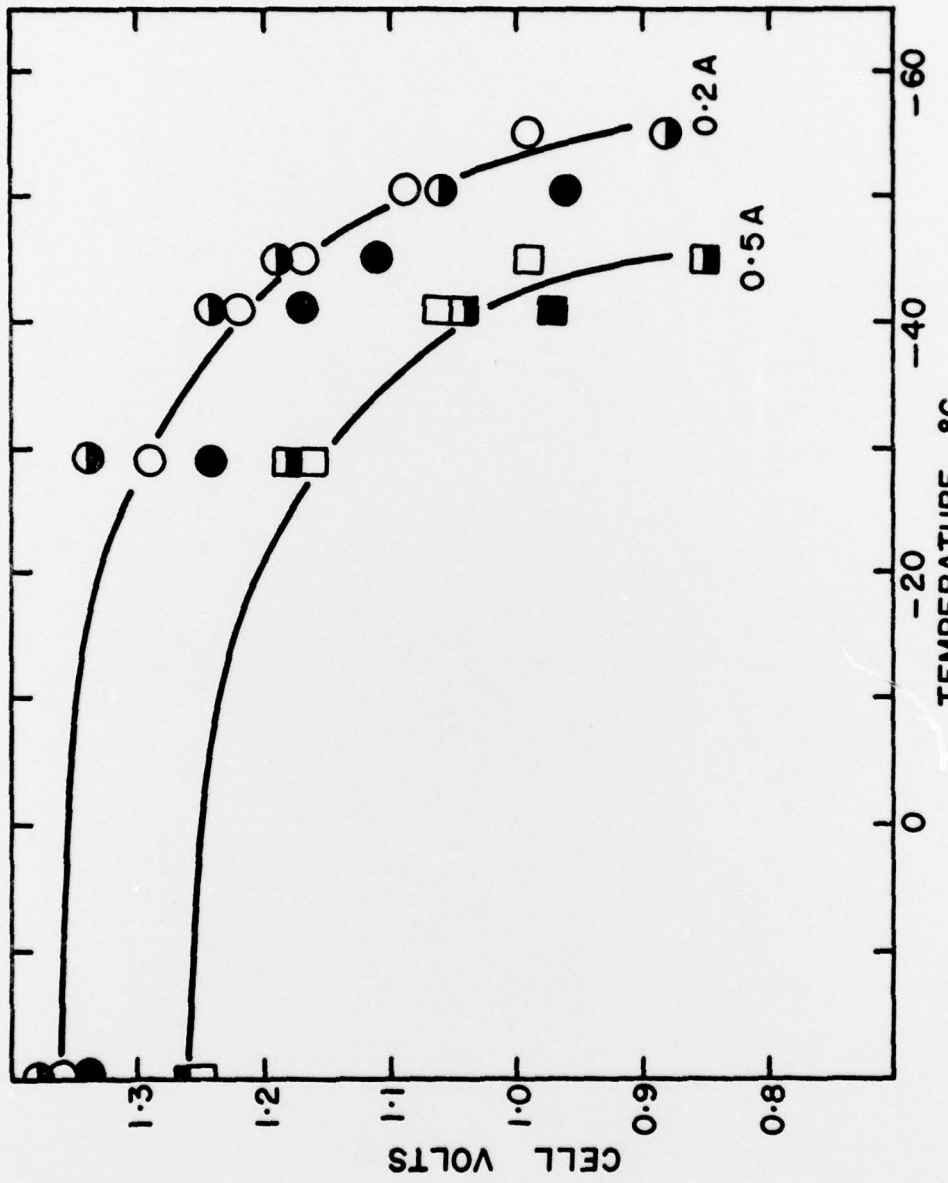

Fig. 12: Effect of Temperature on Cell Voltage After Nine Month Discharge at 0.2A. □ ,○ 22% KOH, ◨ ,◐ 27% KOH, ■ ,● 29% KOH.

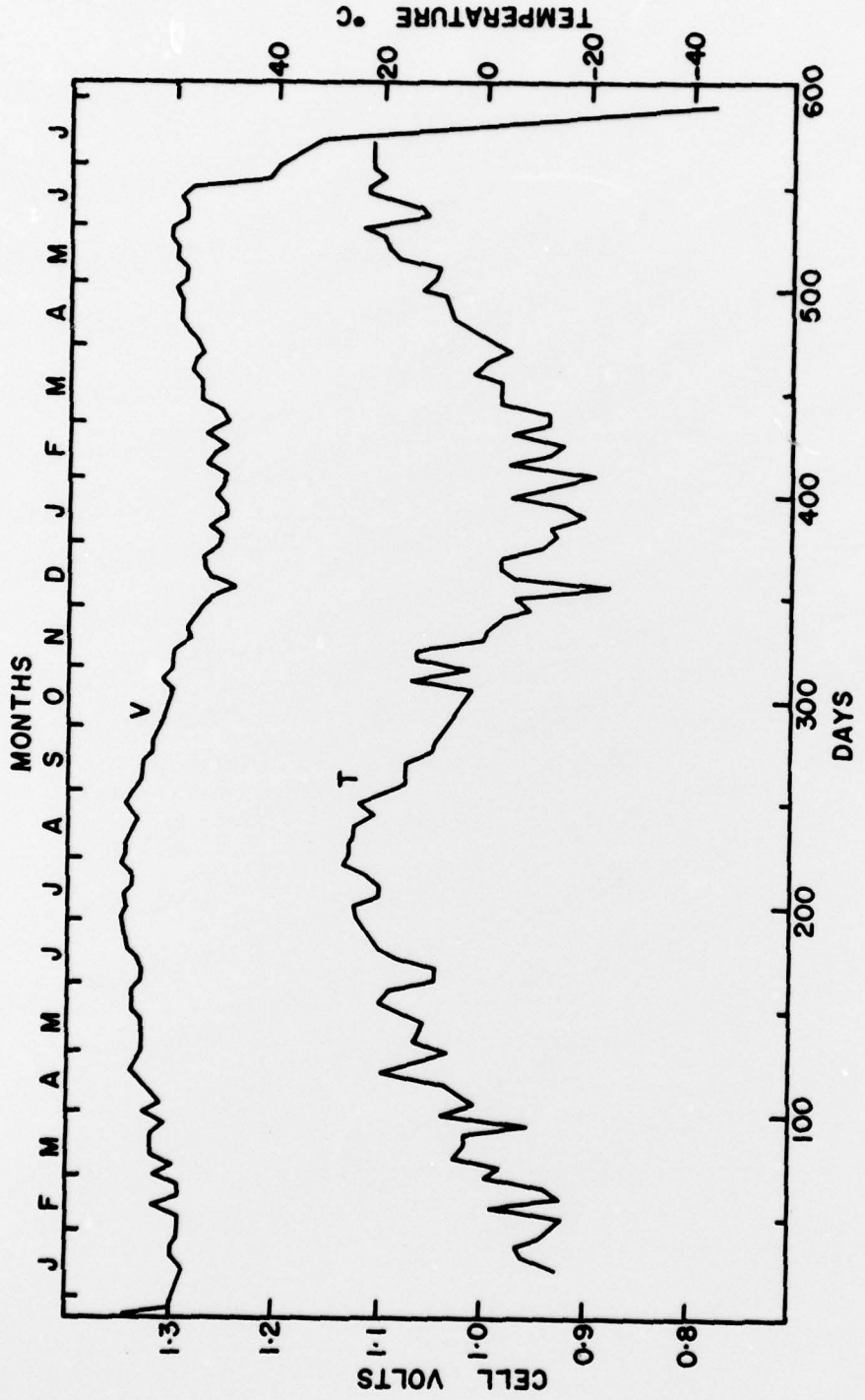

Fig. 13: Voltage and Temperature Variations During Extended Discharge at 0.2A. V - Cell Voltage, T - Ambient Temperature.

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13. ABSTRACT

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PRIMARY BATTERY

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ARCTIC

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